Hydrodynamical Models of Type II-P Supernova Light Curves

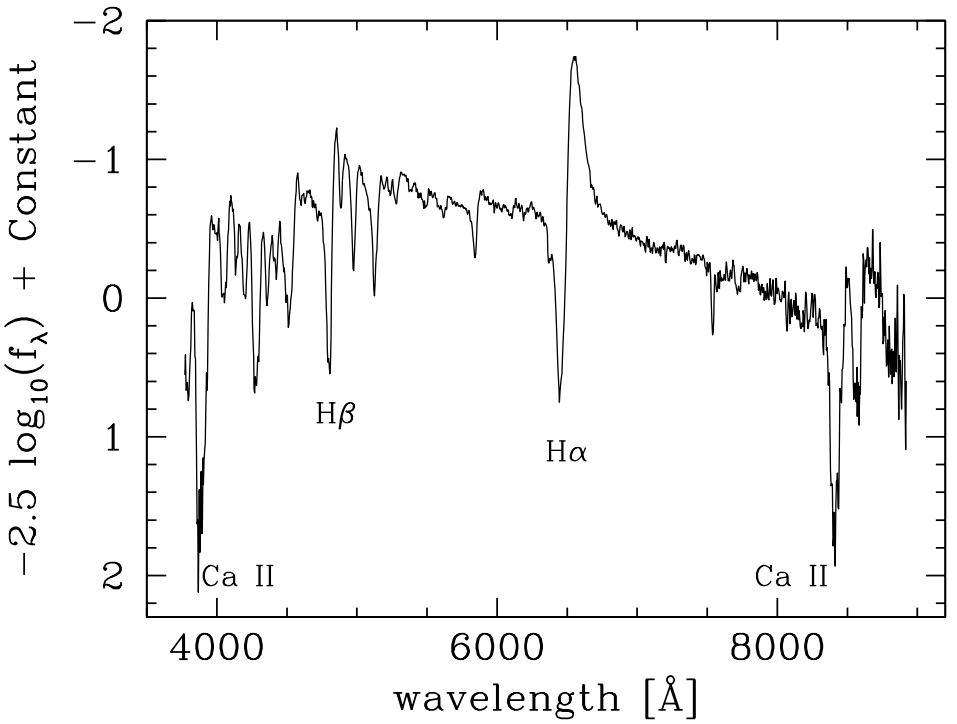
Melina Cecilia Bersten

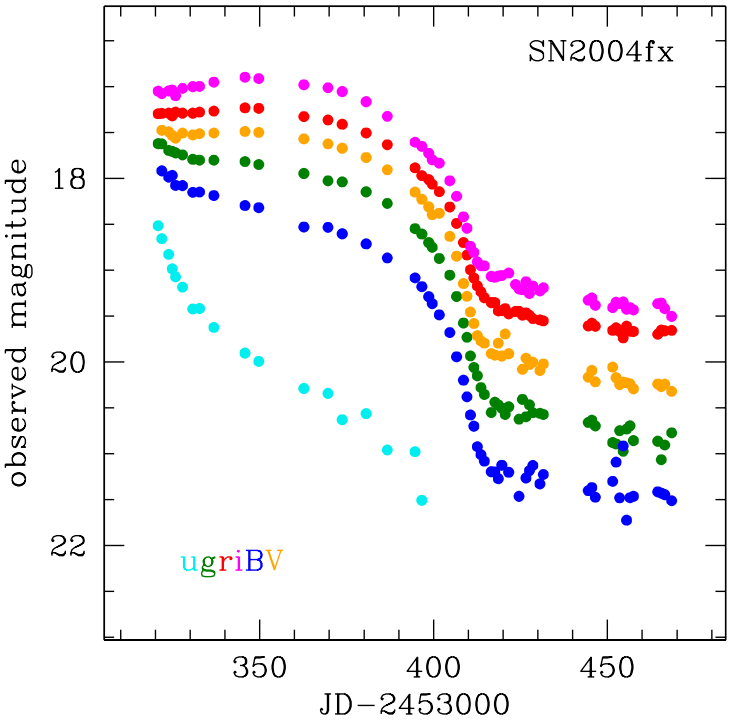
Universidad de Chile

Type II-P Supernovae

Observation

- Spectroscopy: prominent P-Cygni Balmer lines
- Photometry: long plateau phase (L $\sim$ const. for $\sim$100 days)
- Spectropolarimetric: explosion approximately spherical





Courtesy CSP

Type II-P Supernovae

Observation

- Spectroscopy: prominent P-Cygni Balmer lines
- Photometry: long plateau phase (L $\sim$ const. for $\sim$100 days)
- Spectropolarimetric: explosion approximately spherical
- Most common type of SN

Theory

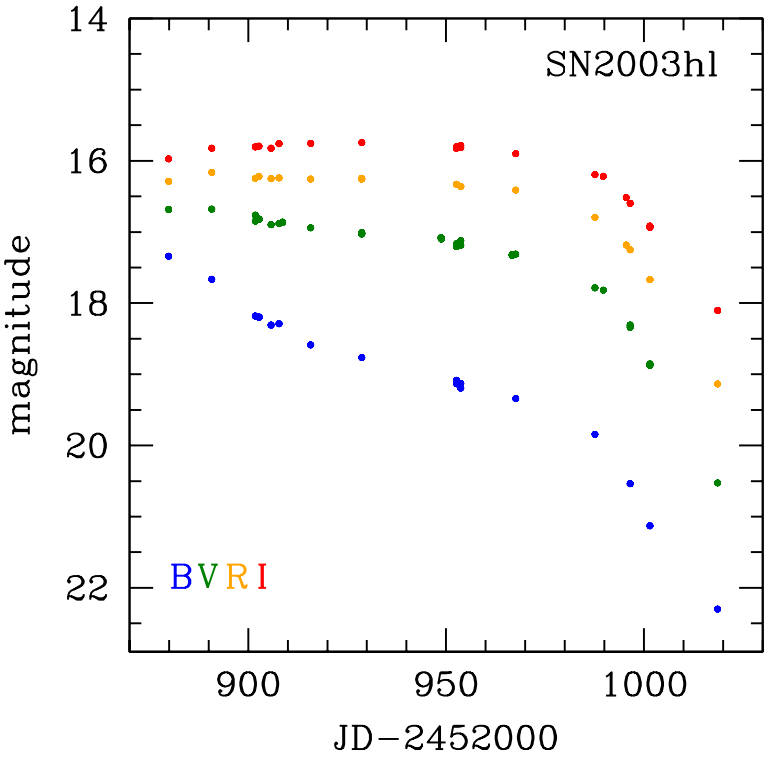
- Core-collapse supernovae
- Progenitor (M_{ZAMS} : $8 - 25 M_{\odot}$): Red supergiant structure with H-rich envelope
- Compact remnant left after the explosion

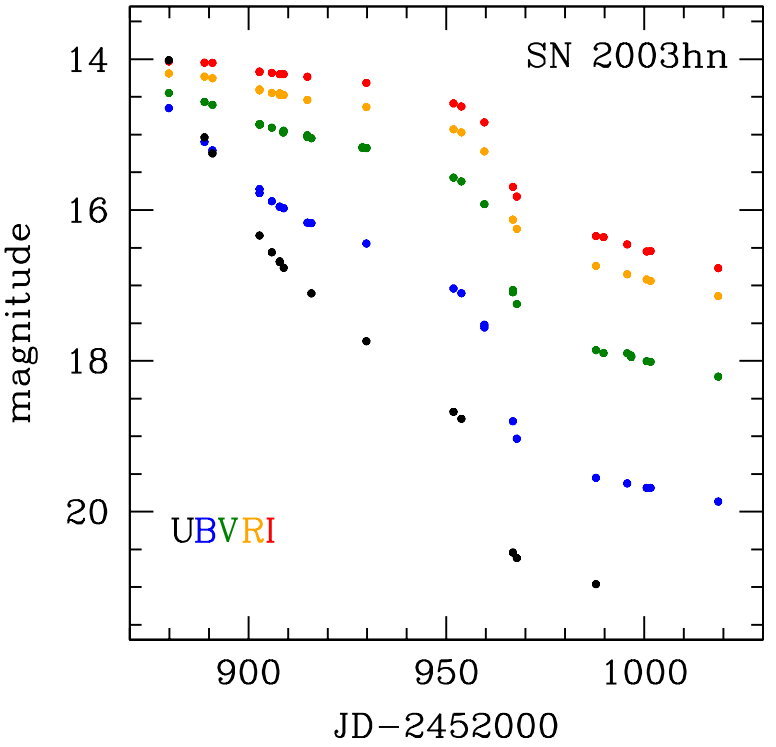
Motivations

- Availability of a large database of high quality data of SN II-P from ongoing surveys such as the CSP

Sample of supernovae

- $\sim$ 33 nearby SNe II-P: Calán/Tololo, SOIRS and CATS (1986-2003)
- High-quality, well-sampled $BVRI$ light curves and spectra
- The CSP is providing even more objects ($\sim$ 80 SNe II-P)





Motivations

- Availability of a large database of high quality data of SN II-P from ongoing surveys such as the CSP
- Better knowledge of physical parameters of SN II-P

Motivations

- Availability of a large database of high quality data of SN II-P from ongoing surveys such as the CSP

- Better knowledge of physical parameters of SN II-P

Determine E_{exp}, M_{ej}, R_0 and M_{Ni} by comparing hydrodynamical models with observations

Motivations

- Availability of a large database of high quality data of SN II-P from ongoing surveys such as the CSP

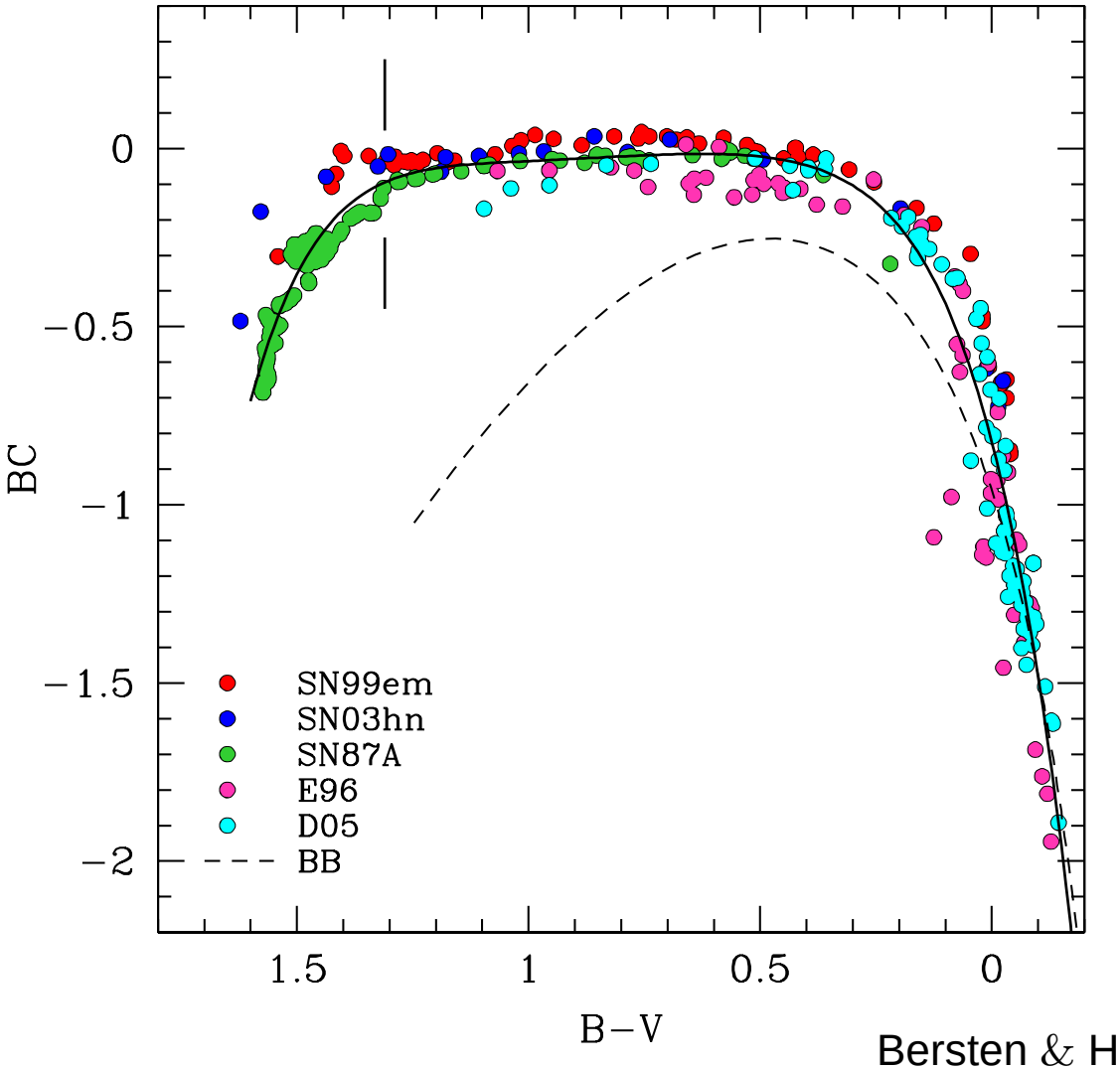
- Better knowledge of physical parameters of SN II-P

Determine E_{exp}, M_{ej}, R_0 and M_{Ni} by comparing hydrodynamical models with observations

- (1) Data: bolometric correction $\Longrightarrow$ bolometric light curve (LC) from BVI photometry
- (2) Model: hydrodynamical code $\Longrightarrow$ theoretical bolometric LC

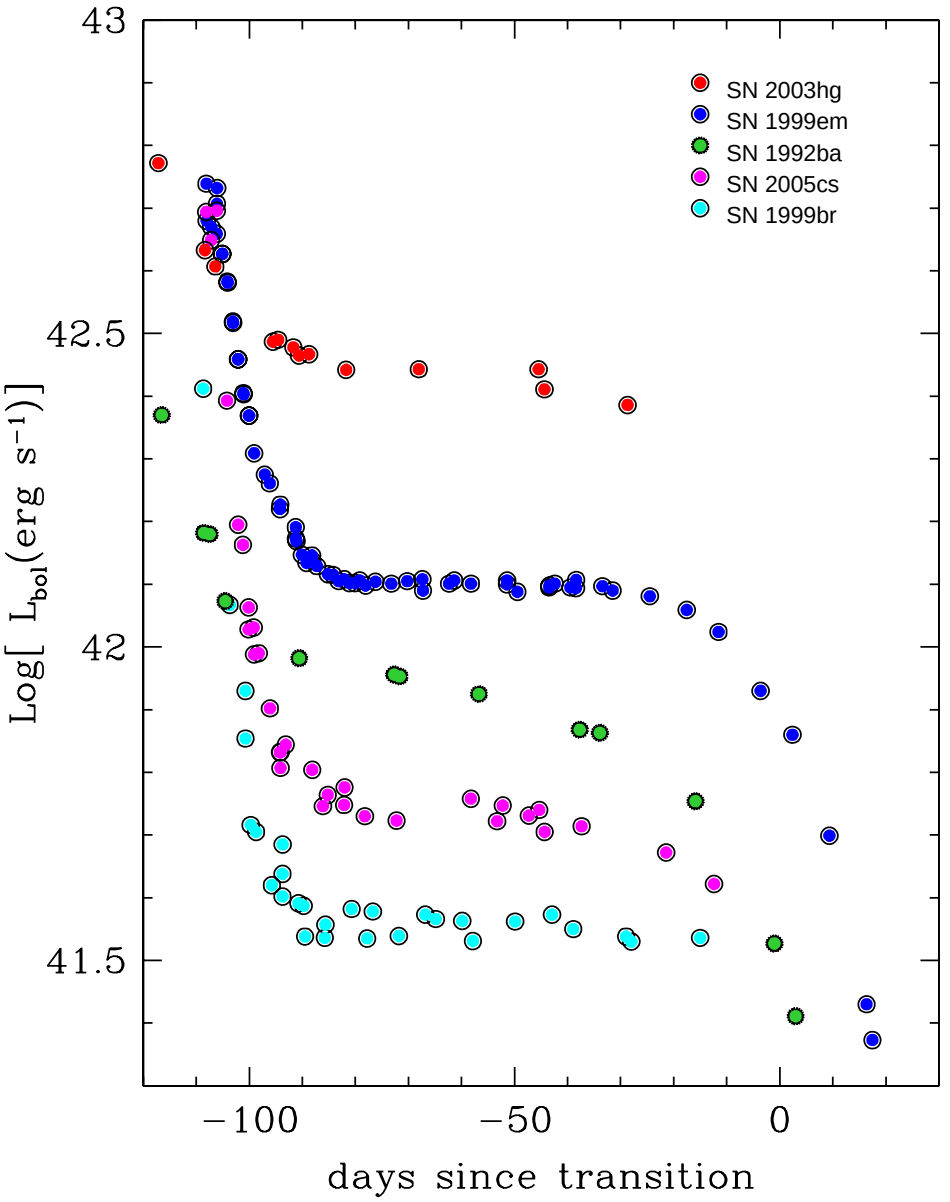
(1) Bolometric Correction

$$BC = m_{bol} - [V - A_V], \quad rms = 0.11 \text{ mag}$$



Bersten & Hamuy (2009)

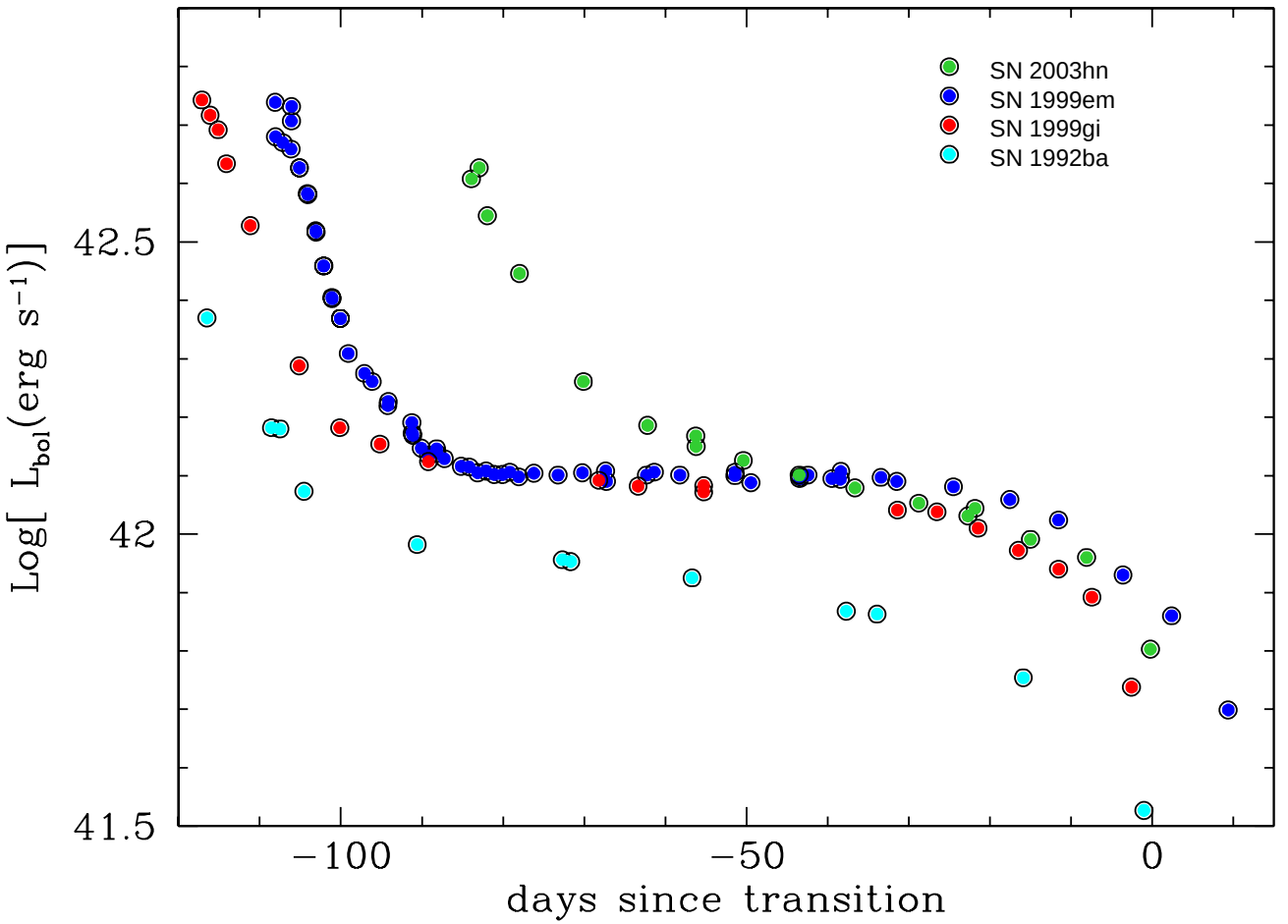
Bolometric Luminosity Range



For our SN sample:

- Bolometric luminosity from BC vs. $B-V$
- Origin of time at midpoint between plateau and radioactive tail
- $\sim$1 dex range in plateau luminosity

Plateau Lengths



Plateau durations between 75 and 120 days

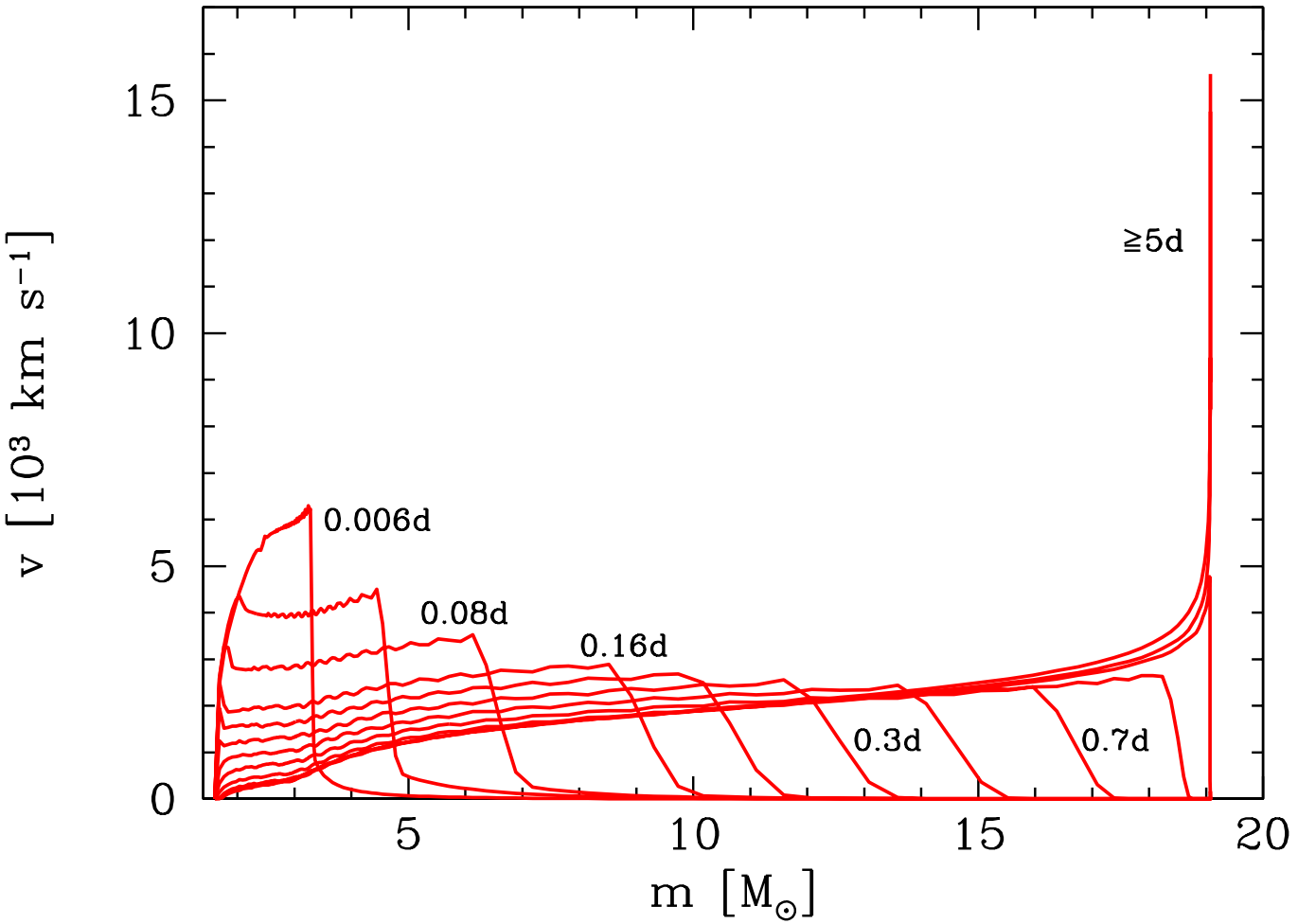
(2) Code

- Numerical integration of the hydrodynamic equations $+$ radiative transfer under some assumptions:
  - Spherically symmetric explosion $\Longrightarrow$ One-dimensional code
  - Diffusion approximation with flux-limited prescription
  - Computation of shock wave using an *artificial viscosity* term
  - Explosion simulated by a sudden release of energy near the core
  - Energy released by radioactive decay included using gray transfer for gamma-rays
- Double Polytropic as initial model

Before breakout

- Model with $E = 1.3$ foes, $R_0 = 800\ R_\odot$, $M_0 = 19\ M_\odot$

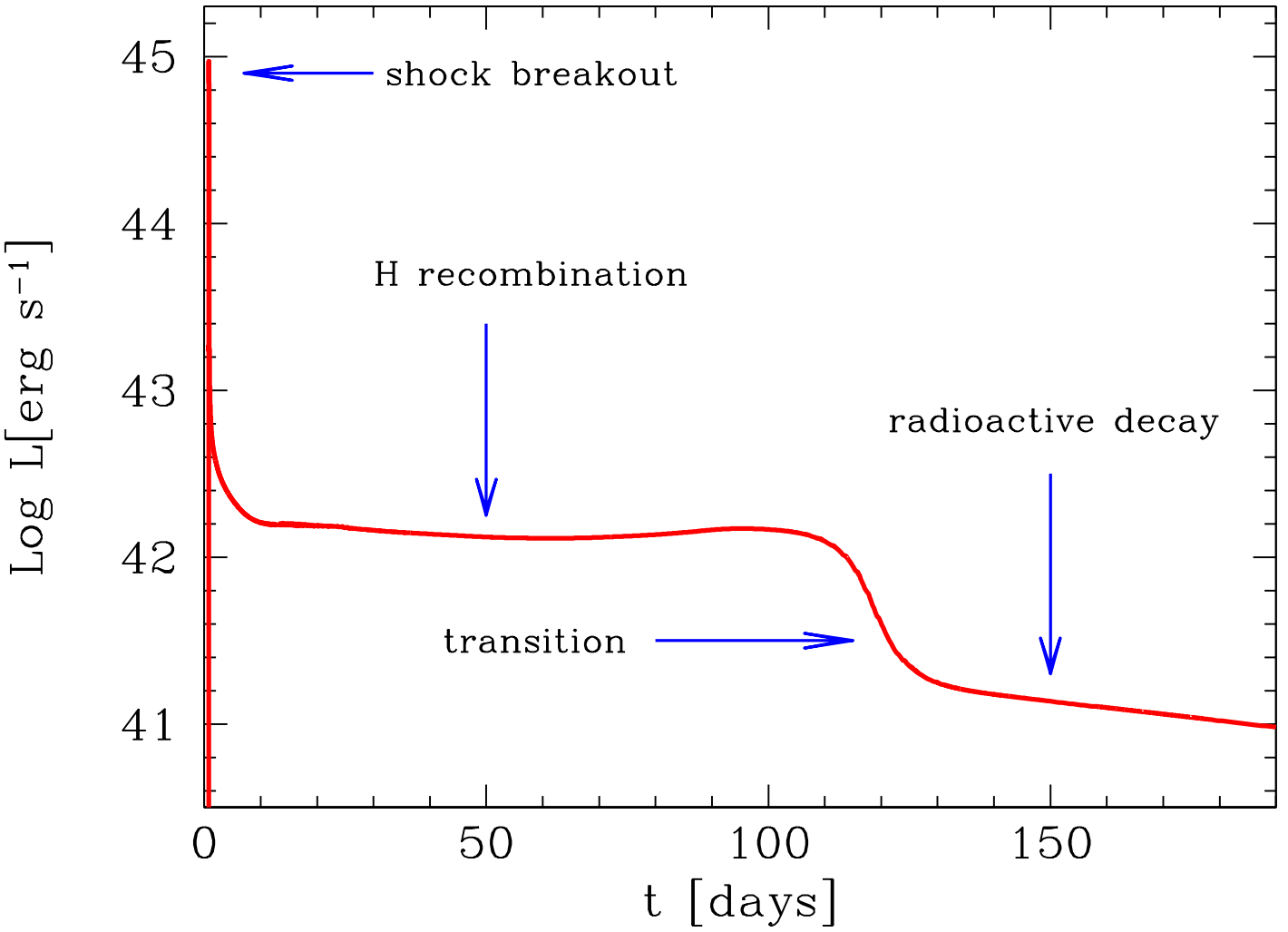
Velocity profiles at different times



Theoretical Bolometric LC

- Model with $E = 1.3$ foes, $R_0 = 800\ R_\odot$, $M_0 = 19\ M_\odot$

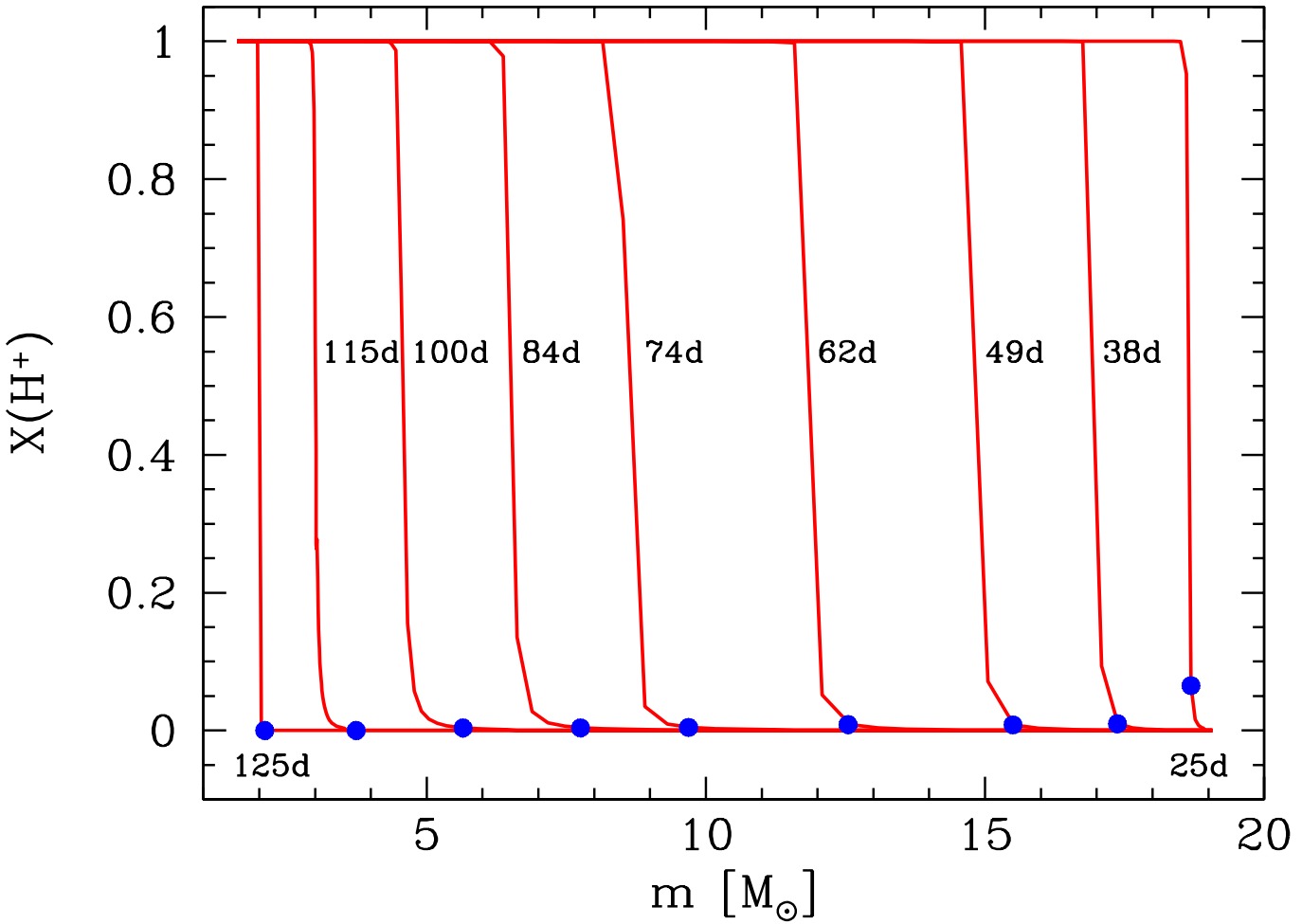
Evolutionary phases



After breakout

- Model with $E = 1.3$ foes, $R_0 = 800\ R_\odot$, $M_0 = 19\ M_\odot$

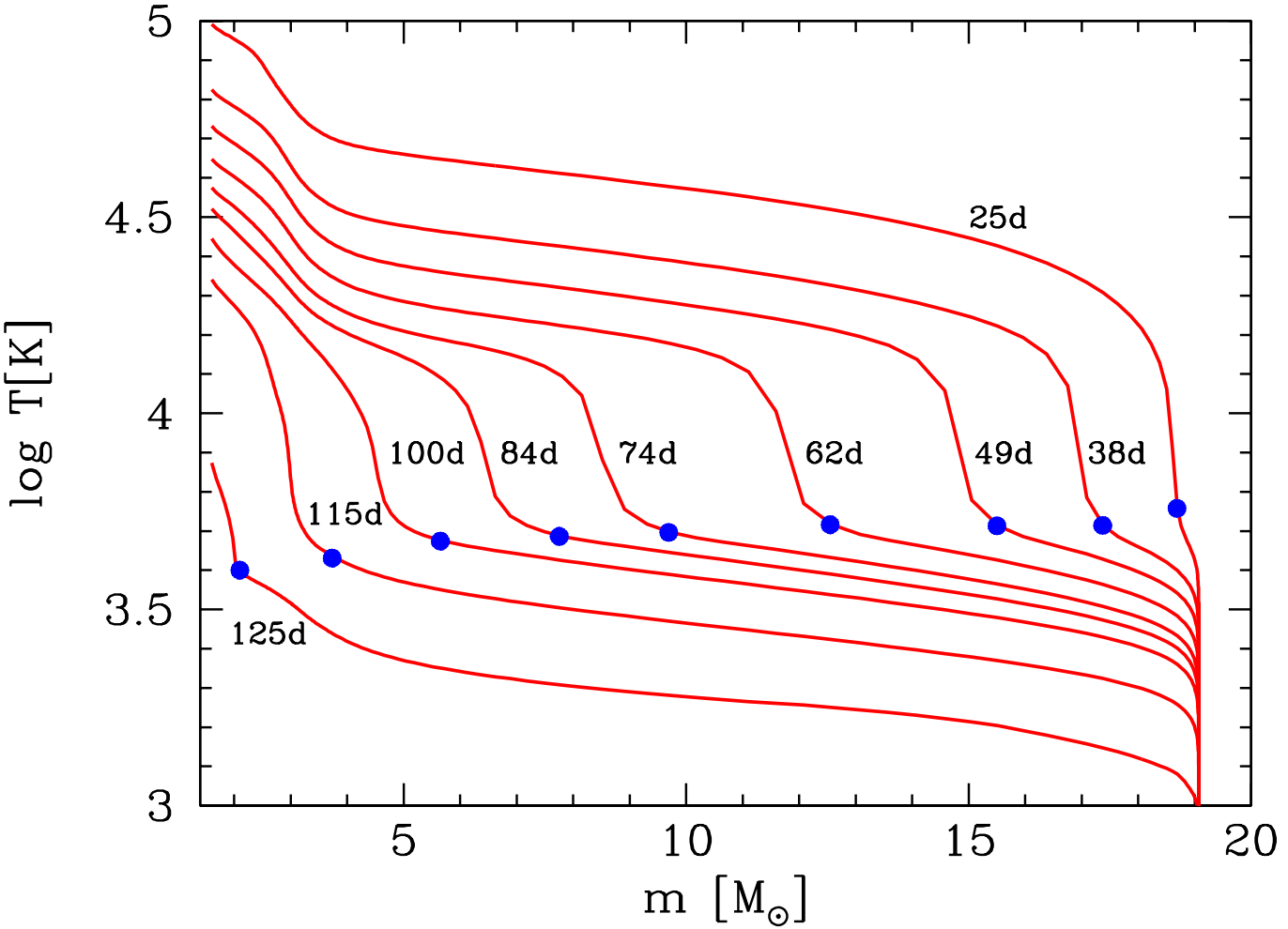
Profiles of the fraction of ionized Hydrogen



After breakout

- Model with $E = 1.3$ foes, $R_0 = 800\ R_\odot$, $M_0 = 19\ M_\odot$

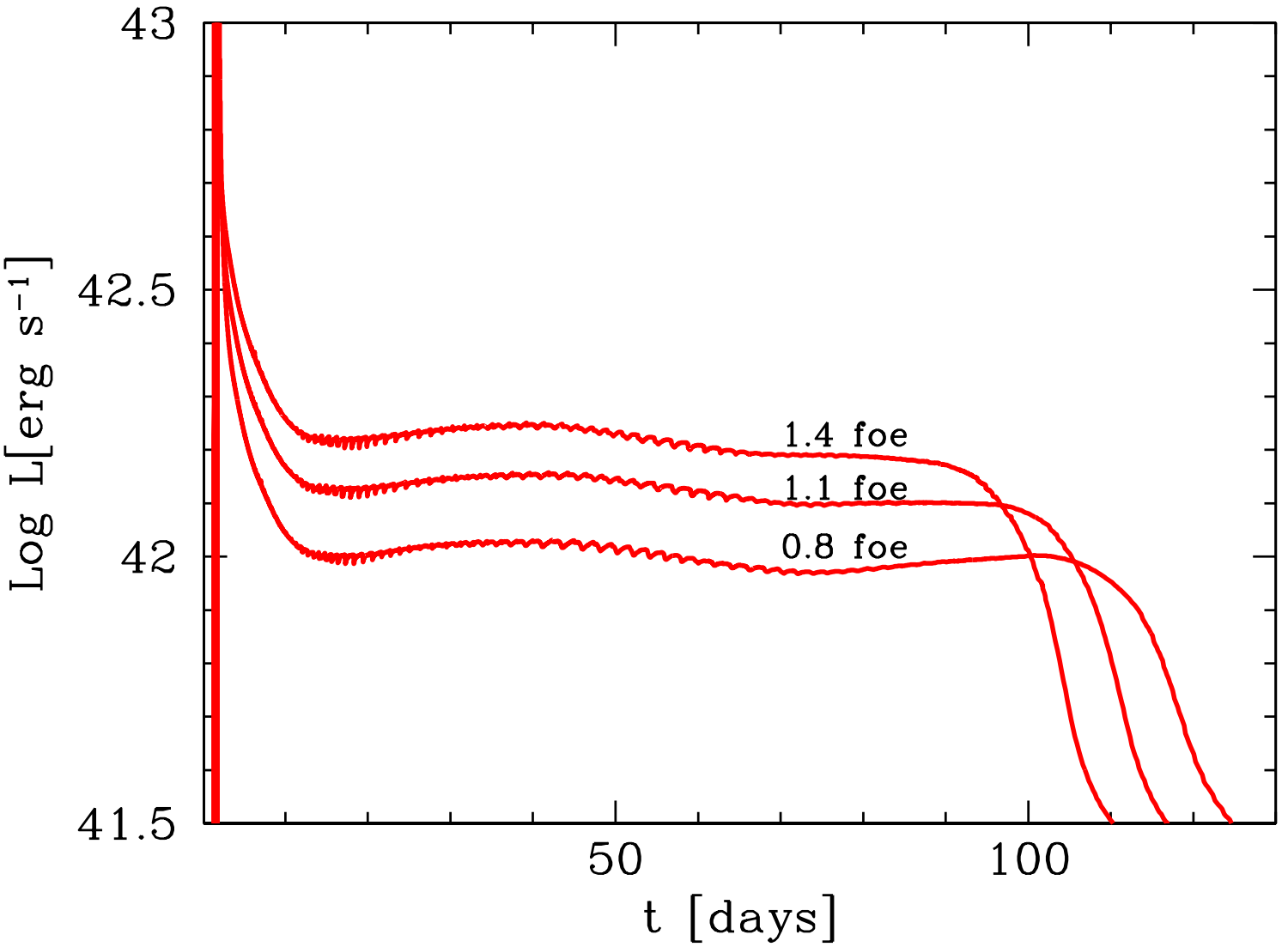
Temperature profiles



Variation of Parameters

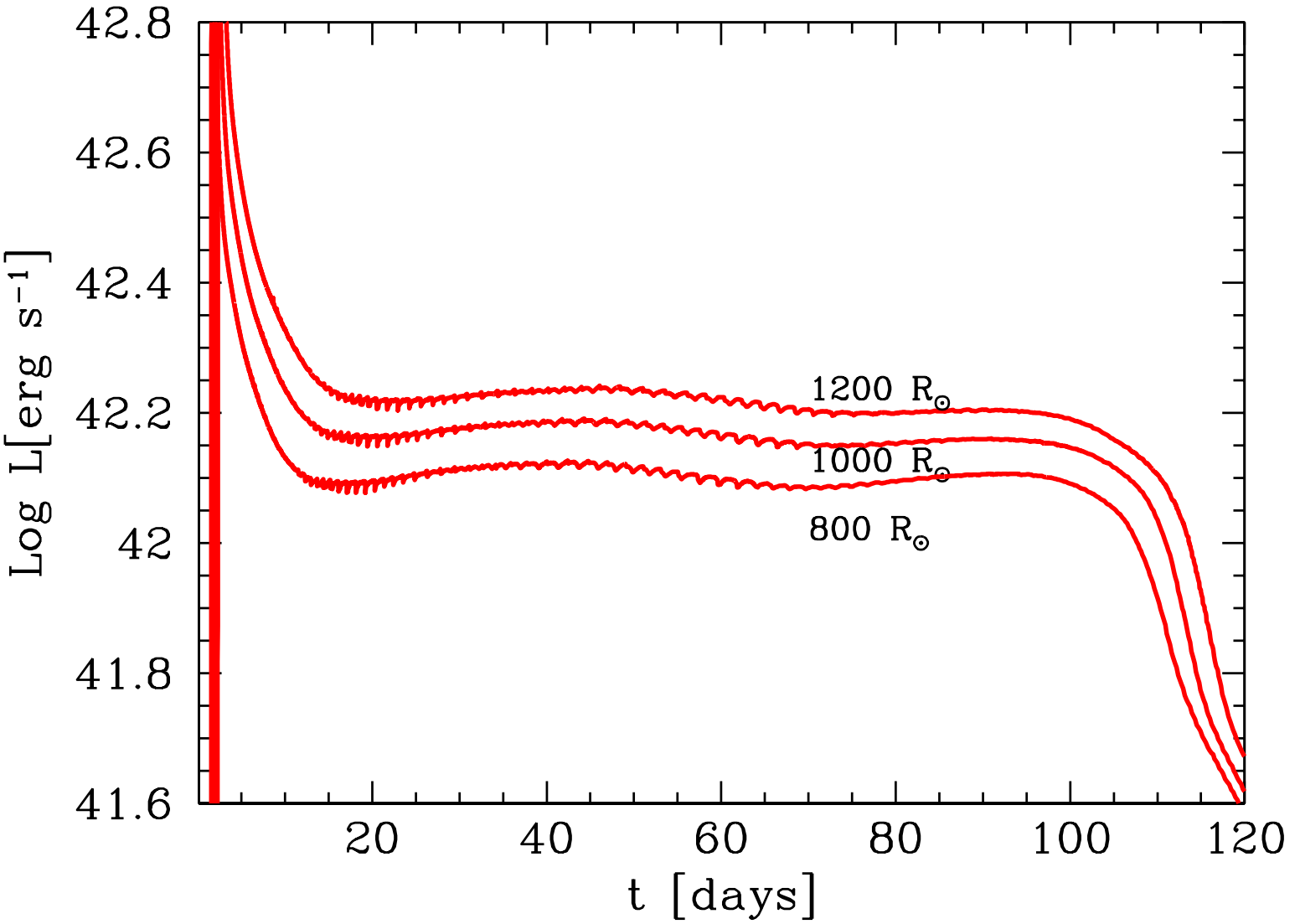
Variation of Parameters

Light curves for different energies



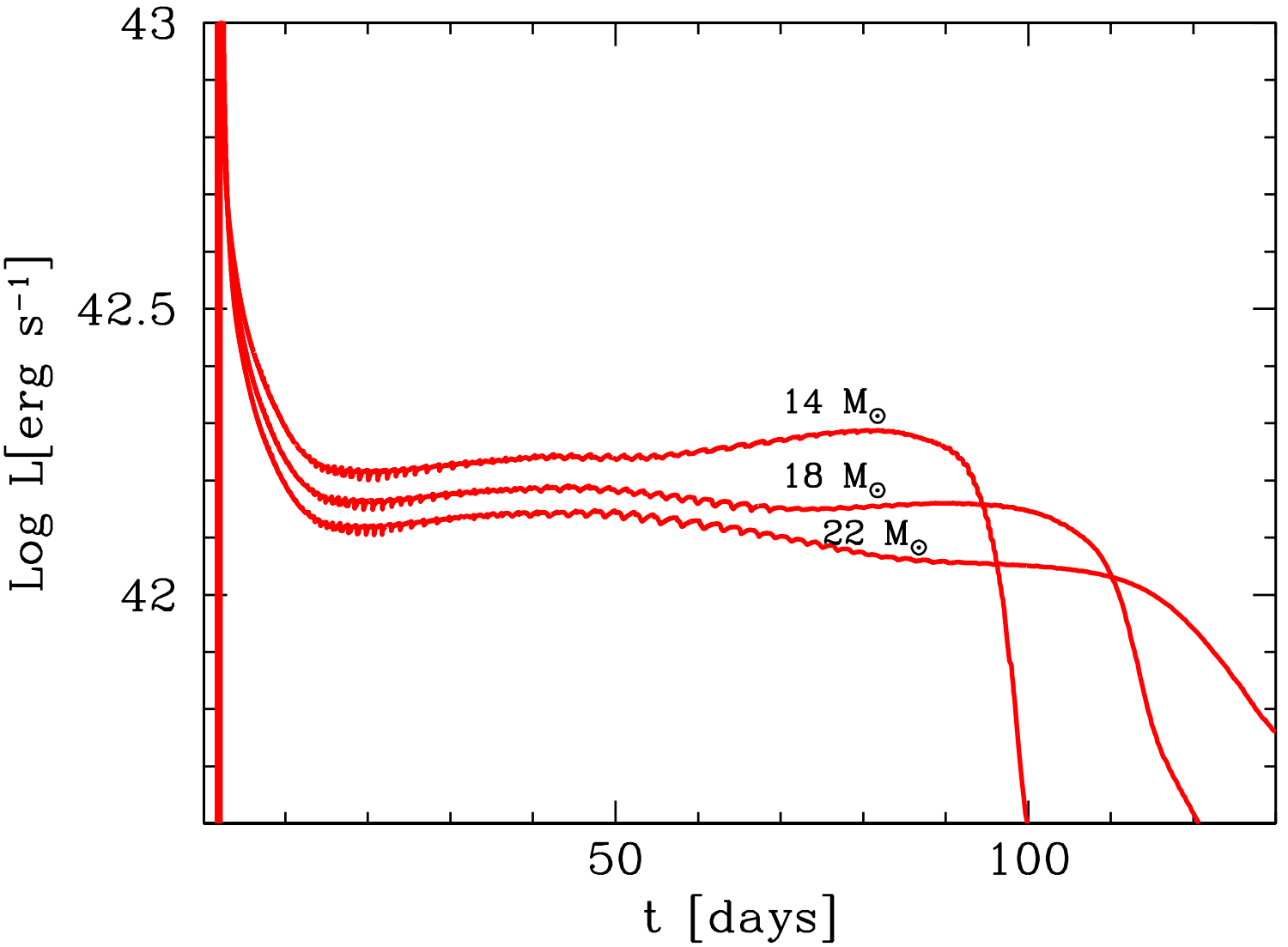
Variation of Parameters

Light curves for different radii



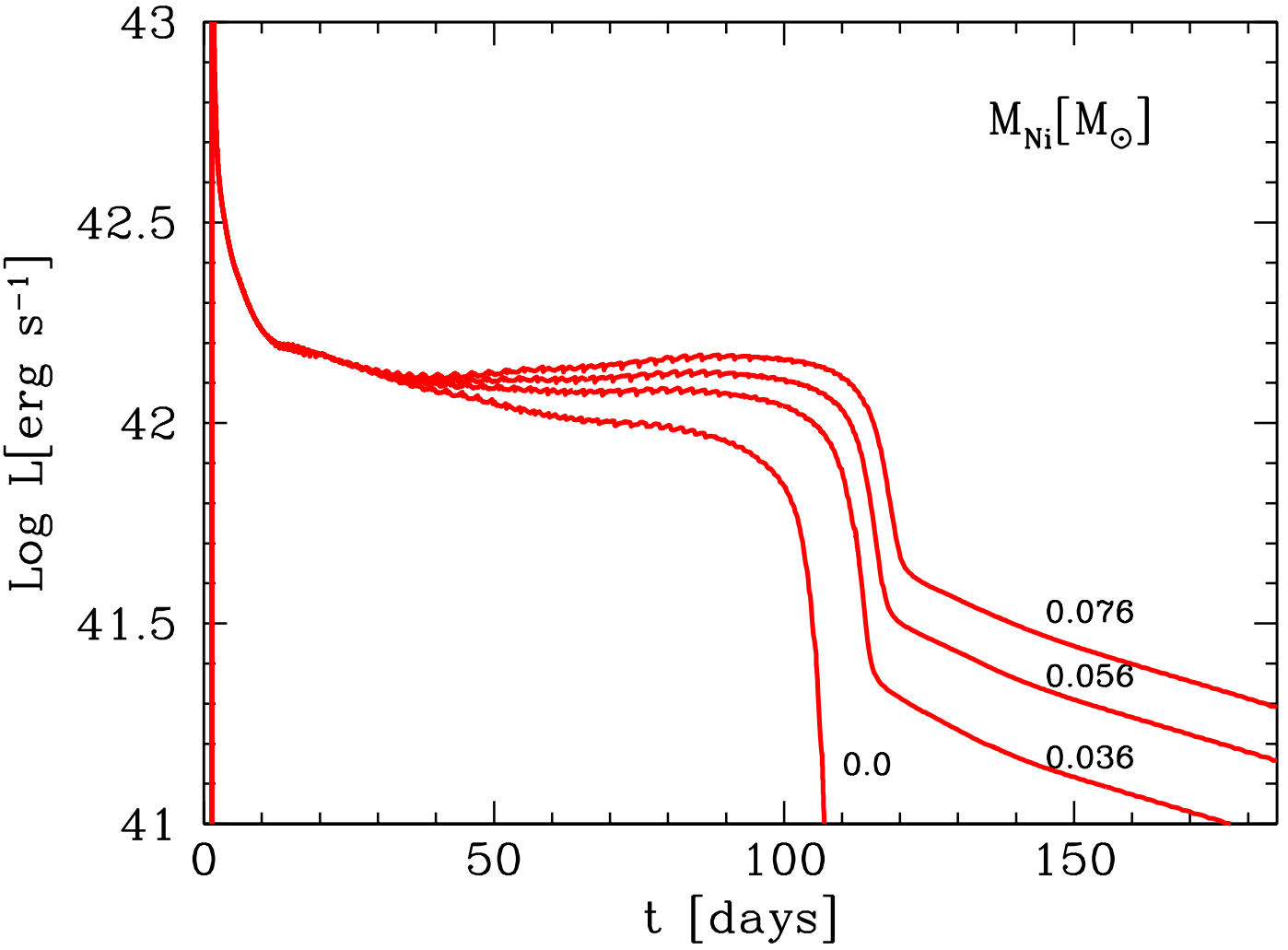
Variation of Parameters

Light curves for different masses



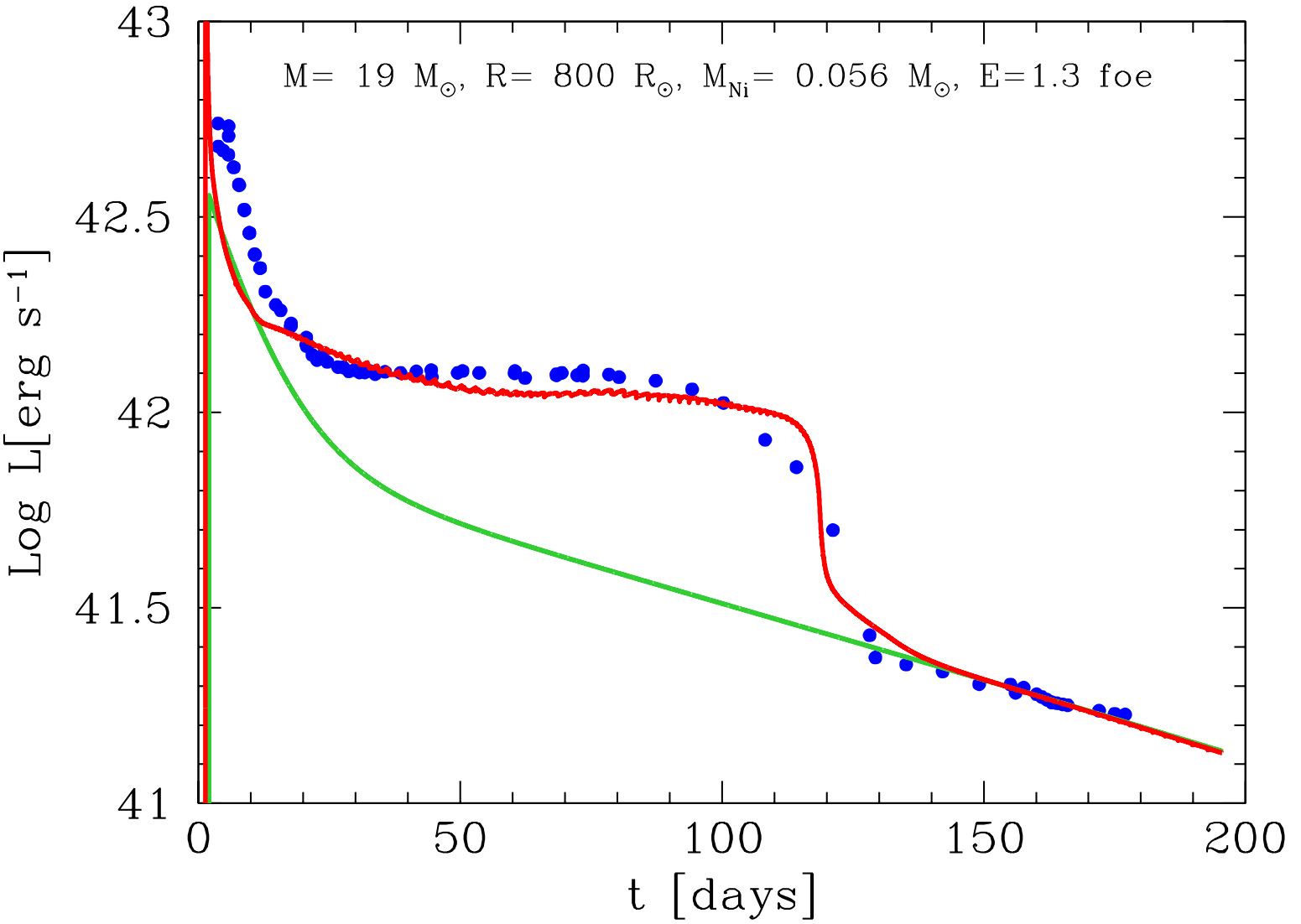
Variation of Parameters

Light curves for different ^{56}Ni mass



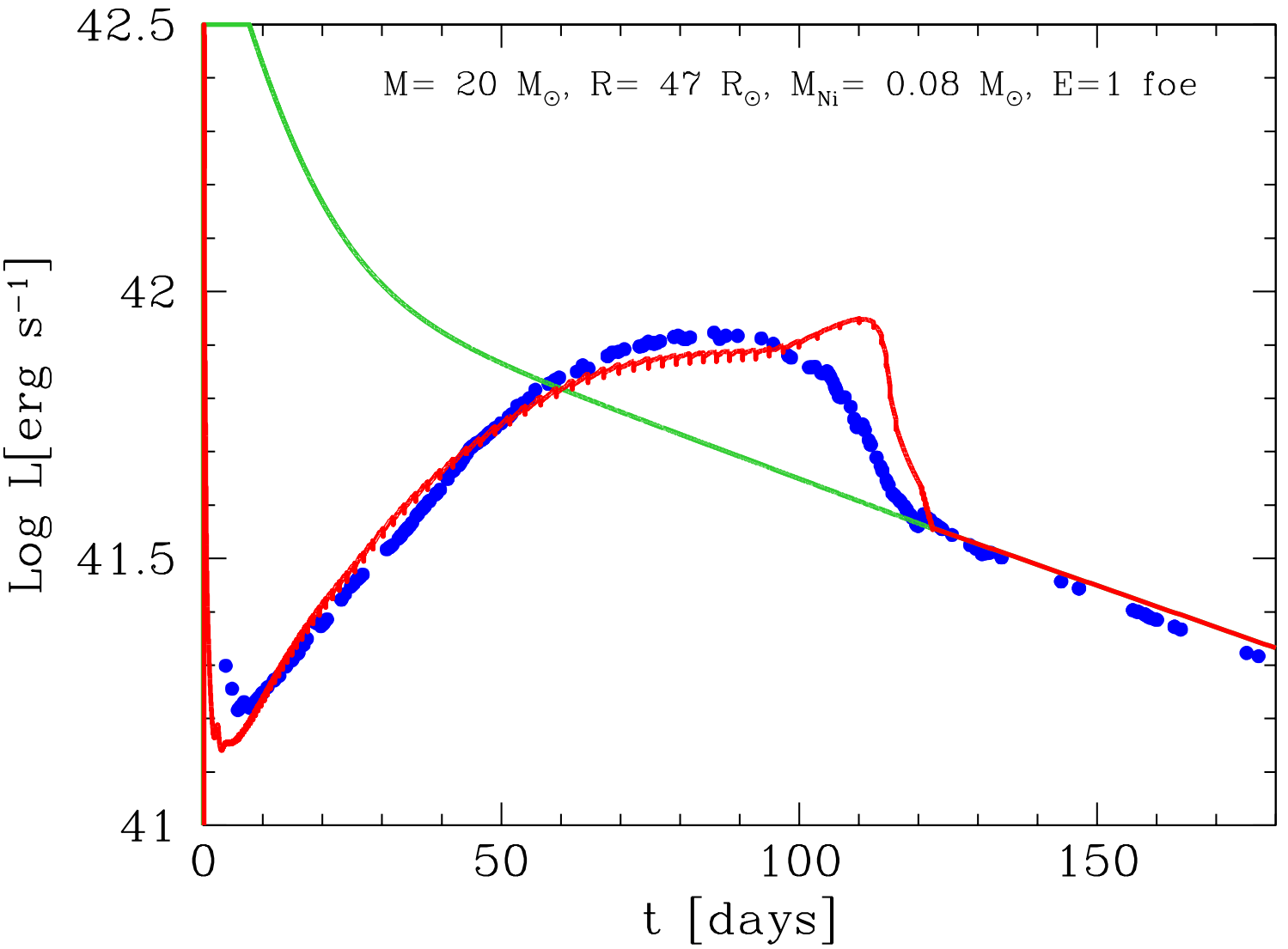
Model vs. Observation

SN 1999em



Model vs. Observation

SN 1987A



Summary

- We developed a hydrodynamical code to obtain bolometric light curves of SNe II-P which is working satisfactorily
- We obtained model fits for SN 1987A and SN 1999em. The resulting physical parameters are consistent with the literature
- We are currently deriving physical parameters for 33 SNe II-P
- We derived reliable calibrations for BC's applicable to SNe II-P with typical scatter of $\sim$0.1 mag
- We calculated bolometric light curves for a sample of 33 SNe II-P
  - 1 dex of differences in plateau luminosities
  - Plateau durations ranged between 75–120 days

Before breakout

- Model with $E = 1.3$ foes, $R_0 = 800\ R_\odot$, $M_0 = 19\ M_\odot$

Density profiles at different times